vaporizing refrigerant cycles to provide refrigeration below about −40° C. and down to about −100° C., and utilizes a gas expander cycle to provide refrigeration below about −100° C. The gas expander cycle also may provide some of the refrigeration in the range of about −40° C. to about −100° C. Each of these two types of refrigerant systems is utilized in an optimum temperature range which maximizes the efficiency of the particular system. Typically, a significant fraction of the total refrigeration power required to liquefy the feed gas (more than 5% and usually more than 10% of the total) can be consumed by the vaporizing refrigerant cycle or cycles. The invention can be implemented in the design of a new liquefaction plant or can be utilized as a retrofit or expansion of an existing plant by adding gas expander refrigeration circuit to the existing plant refrigeration system.

The essential characteristics of the present invention are described completely in the foregoing disclosure. One skilled in the art can understand the invention and make various modifications without departing from the basic spirit of the invention, and without deviating from the scope and equivalents of the claims which follow.

What is claimed is:

1. A method for the liquefaction of a feed gas which comprises providing at least a portion of the total refrigeration required to cool and condense the feed gas by utilizing

(a) a first refrigeration system comprising at least one recirculating refrigeration circuit, wherein the first refrigeration system utilizes two or more refrigerant components and provides refrigeration in a first temperature range; and

(b) a second refrigeration system which provides refrigeration in a second temperature range by work expanding a pressurized gaseous refrigerant stream.

2. The method of claim 1 wherein the lowest temperature in the second temperature range is less than the lowest temperature in the first temperature range.

3. The method of claim 1 wherein at least 5% of the total refrigeration power required to liquefy the feed gas is consumed by the first refrigeration system.

4. The method of claim 1 wherein the feed gas is natural gas.

5. The method of claim 1 wherein the refrigerant in the first recirculating refrigeration circuit comprises two or more components selected from the group consisting of nitrogen, hydrocarbons containing one or more carbon atoms, and halocarbons containing one or more carbon atoms.

6. The method of claim 1 wherein the pressurized gaseous refrigerant stream comprises nitrogen.

7. The method of claim 1 wherein at least a portion of the first temperature range is between about −40° C. and about −100° C.

8. The method of claim 7 wherein at least a portion of the first temperature range is between about −60° C. and about −100° C.

9. The method of claim 1 wherein at least a portion of the second temperature range is below about −100° C.

10. The method of claim 1 wherein at least 10% of the total refrigeration power required to liquefy the feed gas is consumed by the first recirculating refrigeration system.

11. The method of claim 1 wherein the first recirculating refrigeration system is operated by

(1) compressing a first gaseous refrigerant;

(2) cooling and at least partially condensing the resulting compressed refrigerant;

(3) reducing the pressure of the resulting at least partially condensed compressed refrigerant;

(4) vaporizing the resulting reduced-pressure refrigerant to provide refrigeration in the first temperature range and yield a vaporized refrigerant; and

(5) recirculating the vaporized refrigerant to provide the first gaseous refrigerant of (1).

12. The method of claim 11 wherein at least a portion of the cooling of the resulting compressed refrigerant in (2) is provided by indirect heat exchange with vaporizing reduced-pressure refrigerant in (4).

13. The method of claim 11 wherein at least a portion of the cooling in (2) is provided by indirect heat exchange with one or more additional vaporizing refrigerant streams provided by a third recirculating refrigeration circuit.

14. The method of claim 13 wherein the third recirculating refrigeration circuit utilizes a single component refrigerant.

15. The method of claim 13 wherein the third recirculating refrigeration circuit utilizes a mixed refrigerant comprising two or more components.

16. The method of claim 1 wherein the second refrigeration system is operated by

(1) compressing a second gaseous refrigerant to provide the pressurized gaseous refrigerant in (b);

(2) cooling the pressurized gaseous refrigerant to yield a cooled gaseous refrigerant;

(3) work expanding the cooled gaseous refrigerant to provide the cold refrigerant in (b);

(4) warming the cold refrigerant to provide refrigeration in the second temperature range; and

(5) recirculating the resulting warmed refrigerant to provide the second gaseous refrigerant of (1).

17. The method of claim 16 wherein at least a portion of the cooling in (2) is provided by indirect heat exchange by warming the cold refrigerant stream in (4).

18. The method of claim 16 wherein at least a portion of the cooling in (2) is provided by indirect heat exchange with the vaporizing refrigerant of (a).

19. The method of claim 16 wherein at least a portion of the cooling in (2) is provided by indirect heat exchange with one or more additional vaporizing refrigerants provided by a third recirculating refrigeration circuit.

20. The method of claim 19 wherein the third recirculating refrigeration circuit utilizes a single component refrigerant.

21. The method of claim 19 wherein the third recirculating refrigeration circuit utilizes a mixed refrigerant which comprises two or more components.

22. The method of claim 1 wherein the first refrigeration system and the second refrigeration system provide in a single heat exchanger a portion of the total refrigeration required to liquefy the feed gas.

23. The method of claim 1 wherein the first refrigerant system is operated by

(1) compressing a first gaseous refrigerant;

(2) cooling and partially condensing the resulting compressed refrigerant to yield a vapor refrigerant fraction and a liquid refrigerant fraction;

(3) further cooling and reducing the pressure of the liquid refrigerant fraction, and vaporizing the resulting liquid refrigerant fraction to provide refrigeration in the first temperature range and yield a first vaporized refrigerant;

(4) cooling and condensing the vapor refrigerant fraction, reducing the pressure of at least a portion of the resulting liquid, and vaporizing the resulting liquid

refrigerant fraction to provide additional refrigeration in the first temperature range and yield a second vaporized refrigerant; and

(5) combining the first and second vaporized refrigerants to provide the first gaseous refrigerant of (1).

24. The method of claim **23** wherein vaporization of the resulting liquid in (4) is effected at a pressure lower than the vaporization of the resulting liquid refrigerant fraction in (3), and wherein the second vaporized refrigerant is compressed before combining with the first vaporized refrigerant.

25. The method of claim **16** wherein work from work expanding the cooled gaseous refrigerant in (3) provides a portion of the work required for compressing the second gaseous refrigerant in (1).

26. The method of claim **16** wherein the feed gas is natural gas, the resulting liquefied natural gas stream is flashed to lower pressure to yield a light flash vapor and a final liquid product, and the light flash vapor is used to provide the second gaseous refrigerant in the second refrigerant circuit.

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